Title of Investigation:

X-ray Diffractometer for Lunar and Martian Landers

Principal Investigator:

Dr. Keith Gendreau (Code 662)

Other In-house Members of Team:

Dr. Zaven Arzoumanian (Code 662), Dr. Jack Trombka (Code 691), Sam Floyd (Code 691), and Lucy Lim (Code 691)

Other Collaborators:

Najma Khorrami, George Washington University (Student)

Initiation Year:

2004

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

$0

FY 2004 Authorized Funding:

$50,000

Actual or Expected Expenditure of FY 2004 Funding:

In-House: Machine Shop $8,000; Contracts: $32,000 to Roper Scientific; Grants: $5,000 to Najma Khorrami and $5,000 to Dr. Zaven Arzoumanian

Status of Investigation at End of FY 2004:

To be Continued in FY 2005, with funds remaining from FY 2004 and earlier years

Expected Completion Date:

December 2005

Purpose of Investigation:

X-ray diffractometry uses the very small X-ray wavelength as a ruler to measure the spacing between atomic planes in a material. The measured spacings act something like a fingerprint to identify the material. Because of this capability, X-ray diffractometry has become a valuable method for identifying minerals, even at the level of individual organic and inorganic molecules. However, laboratory X-ray diffractometers (XRDs) are large, cumbersome devices that include a very bright X-ray source, a monochrometer, which selects a particular wavelength, a collimated detector, and many moveable stages. They are massive, not particularly rugged, and require a large amount of power. An XRD that is rugged, lightweight, and operates under low power could play a key role in future lunar and planetary landers. It could analyze minerals far beyond what is currently available, and possibly detect signatures of life.

Under this investigation, we are building a lightweight diffractometer that will ultimately operate under low power. It will involve maximizing the photon-counting spectroscopic capabilities of X-ray Charge Coupled Devices (CCDs) to produce the first multi-wavelength X-ray diffractometer system. Figure 1 outlines the device.

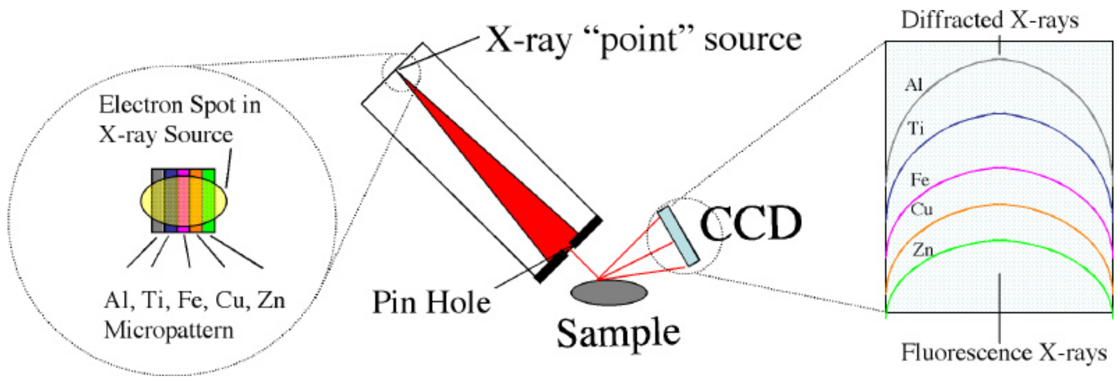

Figure 1: Basic Configuration of our new X-ray Diffractometer. The X-ray source produces multiple characteristic emission lines spanning as much as an order of magnitude of wavelength. The Diffracted X-rays from the sample will be collected by an energy dispersive X-ray CCD. The CCD's energy resolution allows us to separate the different diffracted X-rays by wavelength and hence gives us more sensitivity to different d-spacings in the sample for a fixed configuration.

Objectives:

The objectives of this investigation are two-fold: (1) Provide NASA projects with technology for identifying molecules in a package suitable for a lunar/planetary lander; and (2) Provide NASA with a low-power, X-ray source suitable for a number of instruments, including diffractometers and devices that perform in-flight calibration of X-ray instruments. The source will produce many characteristic X-ray lines simultaneously, while effectively becoming “microfocused” when analyzed by an imaging spectrometer like an X-ray CCD.

Accomplishments to Date:

Funding for this effort began in mid-July 2004. We ordered an X-ray CCD, which still has not arrived. We also designed a sample chamber and have submitted the design to the Goddard machine shop for machining.

We did borrow a CCD from another project and used a very simple chamber, with limited geometry, to demonstrate multi-wavelength X-ray diffractometry. In this experiment, our source was simply a gold target that produces bremmstrahlung (continuum) X-rays. The CCD has a resolving power of about 2% and could separate different wavelength components. Using this, we could see diffracted continuum X-rays. We made different images for different pulse-height ranges in the CCD and could see two diffraction features (corresponding to different d-spacings in our titanium sample) move across the CCD as we changed the energy band. While the spectral width of the diffracted X-rays we saw was broad (limited by the CCD's energy resolution), this test demonstrated the basic principles of our multi-wavelength X-ray diffractometer.

Planned Future Work:

We are expecting our own X-ray CCD for this project to arrive soon. In addition, we will have a sample chamber that will allow us to look optimally for diffraction peaks for a wide range of d-spacings. We also plan to modify the X-ray source so that we can get characteristic emission lines from different elements at the same time for XRD.

Key Points Summary:

The use of an engineered X-ray source, which allows us to fully exploit the CCD's capability and provides an order-of-magnitude more wavelength coverage for faster results, makes this project innovative. The potential payoff to the Goddard Space Flight Center is that the instrument could potentially provide very quick analysis of materials in a small, lightweight package suitable for landers. We will judge our success by whether we can identify a large sample of minerals without moving any parts or preparing the samples in any special way. The technical risk factor that could prevent us from succeeding is manufacturing a multi-target X-ray source that could simultaneously produce multiple wavelengths.